Extensions of the Snoqualmie Transmission

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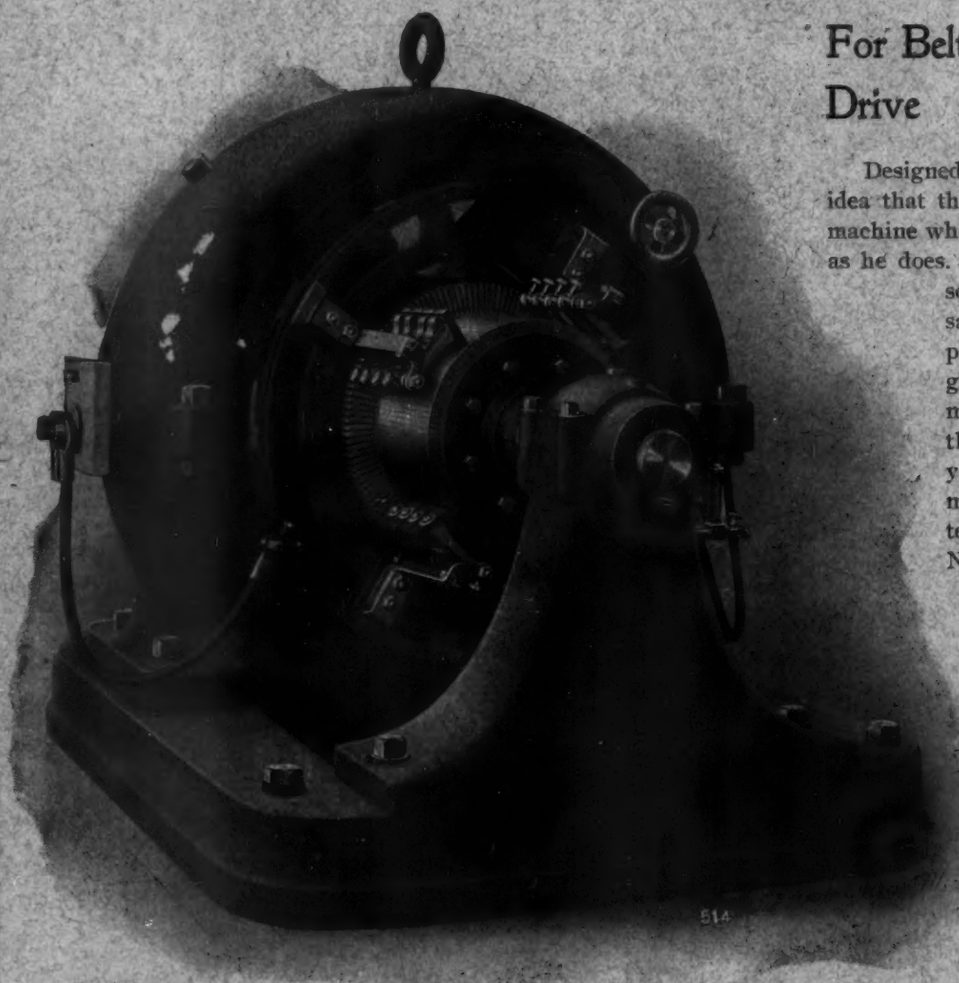

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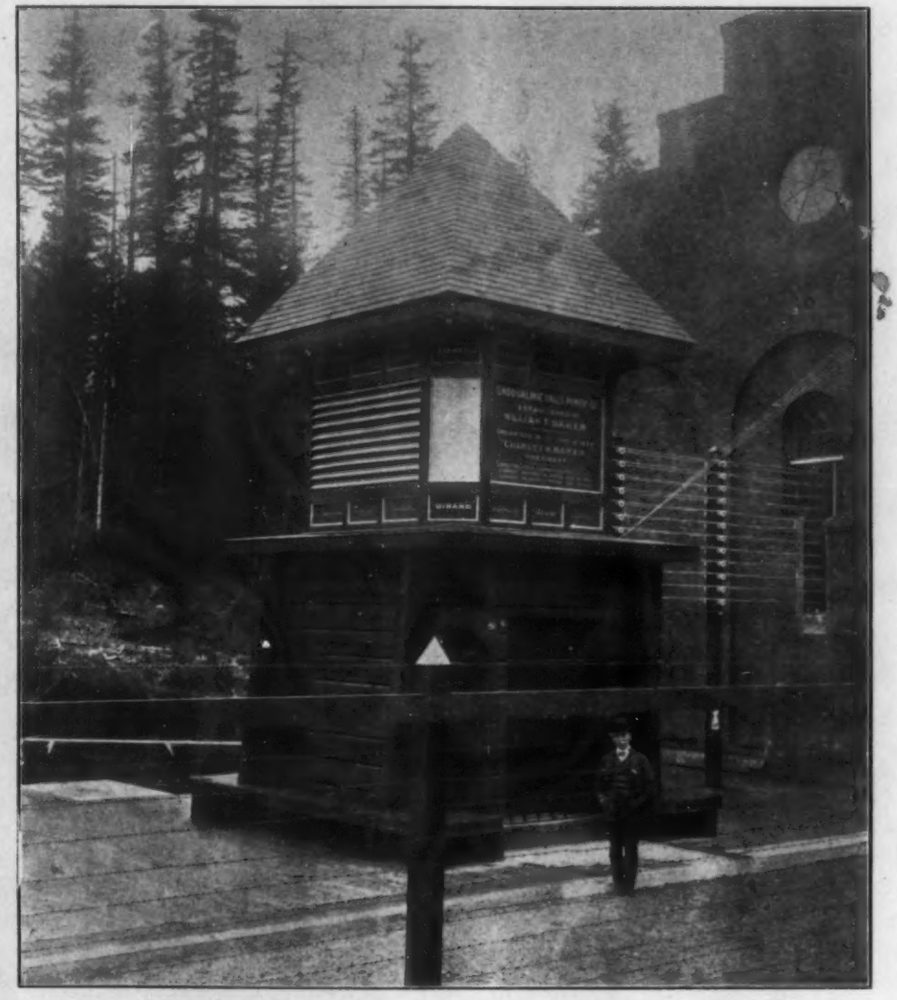
Aesthetics in, and Extensions of the Snoqualmie Transmission.

THE power plant at Snoqualmie Falls has a great many novel features about it in its engineering and practical operation, but it also typifies in its environment and embellishment a different phase, not essential to the manufacture of power, but that which appeals to lofty sentiment and admiration.

President Chas. N. Baker of the Snoqualmie Falls Power Company appears to have a decided taste for the artistic, as well as for the practical and useful. The best exhibition of this is the tower over the shaft crowning the elevator entrance to the subterranean works. It is called by some the "tower of fame," and is well illustrated by the photographs presented herewith, which display two elevations of it. The tower serves as a ventilator for the works besides housing the rigging for the elevator, and is also a protection against a possible extreme high water, as it seals the opening bottle-tight. In outward form it is symmetrical and artistic in its architecture, and is the design of President Baker. It stands about 35 feet high and is 18 feet wide at the base. There is a harmony and consistency of the whole idea and the design, which appeals to the observer. The base of the tower is made of huge logs coated with asphalt, which gives weight and dignity to the structure. The artistic has been confined to the cupola, which the photographs well illustrate.



FRONT VIEW OF THE "TOWER OF FAME" AT SNOQUALMIE FALLS.

The front panel contains the inscription of the company, in gilt letters upon a sanded background of maroon, as follows: Snoqualmie Falls Power Company; Established by William T. Baker; Organized A. D. Jan. 18, 1898; Charles H. Baker, President; Construction commenced April 18th, 1898; Current delivered in Seattle July 31st, 1899; Current delivered in Tacoma Nov. 30th, 1899.

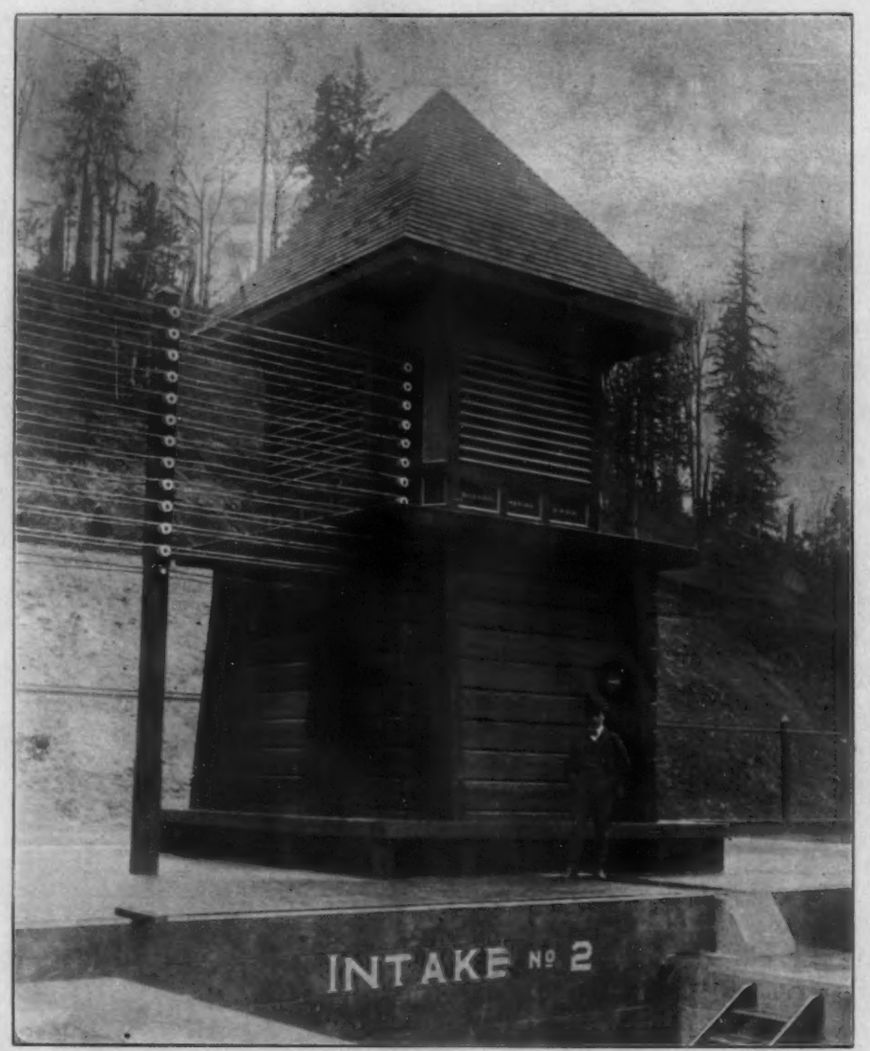
The frieze is divided into smaller panels, containing the names of men prominent in hydraulic science, and these names are Knight, Fontaine, Hesse, Jonval, Venturi, Eads, Pelton, Doble, Waring, DeLesseps, Girard, Fourneyron, Branca, Atkins, Poncelet. At the base of the cupola of the tower, the names best illustrating the exponents of electrical power development appear, as follows: Faraday, Franklin, Kelvin, Siemens,

Edison, Westinghouse, Brush, Ohm, Morse, Ampere, Bell, Volta, Sprague, Lamme, Steinmetz, Tesla.

The grounds around the headworks at Snoqualmie Falls, comprising in all about fifteen acres, have been laid out in a park, the landscape treatment of which is very effective. Green terraces border the river front, and there has been a tasteful planting of shrubbery, hedges, ornamental trees, etc., all of which is relieved here and there by flower beds, where roses and geraniums add color to the landscape. All of this has a fitting setting in the magnificent panorama of the natural scenery of the Snoqualmie river, the woodlands, the valleys, and in bold relief, the snow-capped range to the east, of the Cascade mountains.

Visitors to the falls invariably comment upon the beautiful surroundings, and upon the comfort and happiness of the employes of the works.

The architectural features of two other structures now being erected by the associated corporations of the Snoqualmie Falls Power Company, namely, the new substations of the Seattle Cataract Company and the Tacoma Cataract Company respectively, also embody original and striking innovations. The building for the Seattle Cataract Company is on Seventh avenue and Jefferson street, in Seattle, about a block away from the county courthouse. The site selected is on high ground and therefore has a commanding position. It has the further advantage of being removed from the smoke of the city, which has a deleterious effect on the insulators of high tension transmission lines. This building will be one of the most striking structures in the city and its great dome, lighted by electricity, will be one of the most prominent landmarks, as it will be visible from nearly every approach to the city. Concerning the uses of this building, and his reasons for erecting it at this time, Charles H. Baker, also president of the subsidiary cataract companies, states that the experience of the Seattle Cataract Company during the last year has led to the conclusion that the present basement arrangement in the building at the corner of Second avenue and Main street is unsatisfactory for many reasons and that it is very much cramped as to space. It therefore became apparent that a new plan had better be adopted while the company was yet in its infancy. Knowing that such a change was in contemplation, the city authorities very strongly urged the placing of the new station outside the limits of the tall business structures in the retail business district, and the present site, which was selected in harmony with these views and his own, is extremely well adopted for the purposes. It has the particular advantage of being somewhat isolated and protected by ample open areas around it, so that in case of a general conflagration in the city, the plant would not be destroyed and the city would not be handicapped thereby for lack of lighting facilities and power.



A REAR VIEW OF THE "TOWER OF FAME."

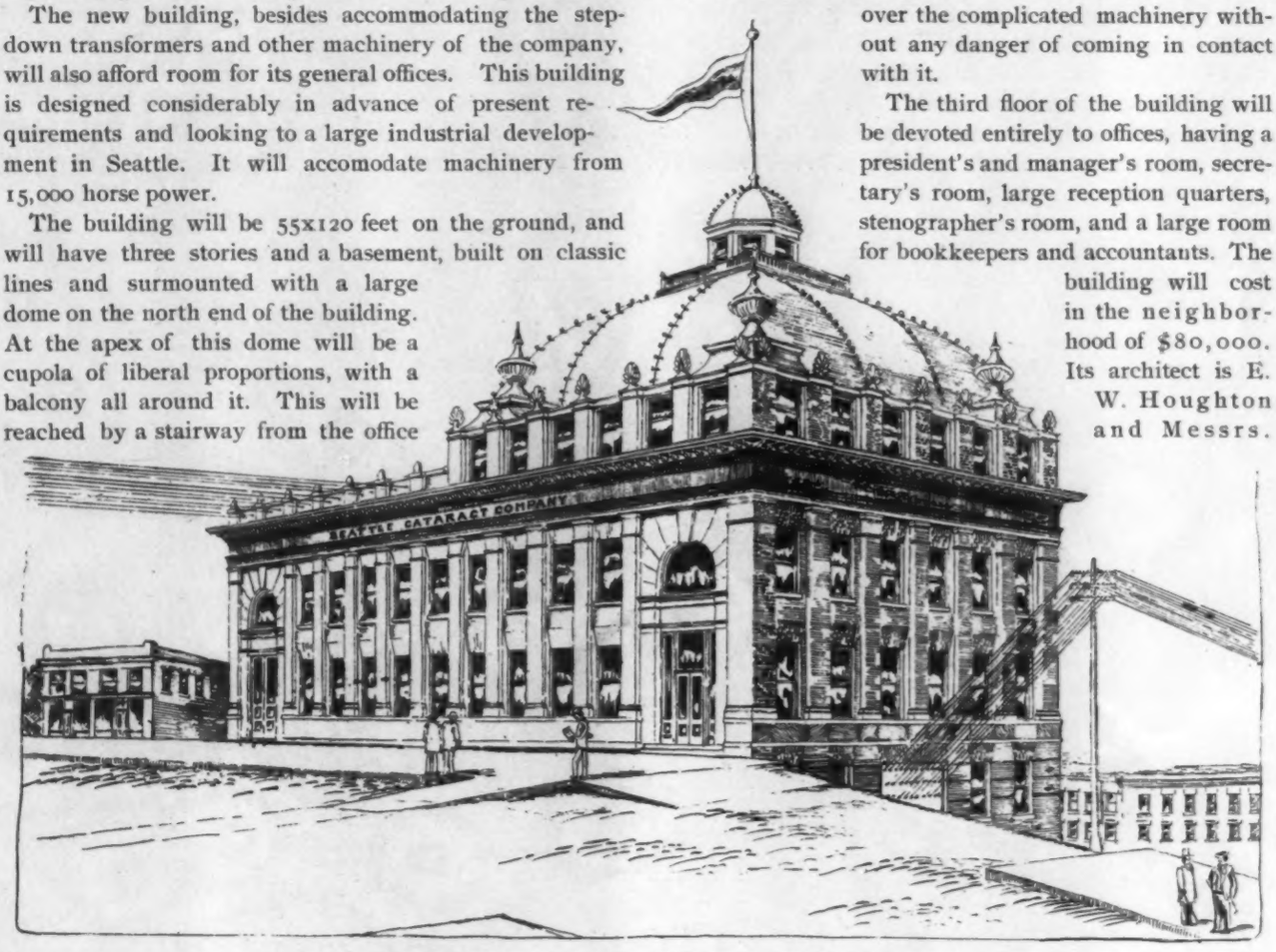
Another advantage of the location is its high altitude, which brings it out of the smoke and soot prevailing in the down-town districts, heretofore a menace to the insulators on the incoming high tension transmission lines. The clearer atmosphere of the higher altitude will obviate this.

From the new station will emanate the distribution to the customers of the company, the principal of these being the circuits running to the new power station of the Seattle Electric Company on Post street, where 3000

horse power will be delivered for the purpose of operating the street cars and electric lighting systems in the city. The 25,000-volt current will be received here from the generating station at the falls and transformed down to 2200 volts for general use. The station will be equipped with a traveling crane for the purpose of lifting and moving heavy parts from one place to another expeditiously.

The new building, besides accommodating the step-down transformers and other machinery of the company, will also afford room for its general offices. This building is designed considerably in advance of present requirements and looking to a large industrial development in Seattle. It will accomodate machinery from 15,000 horse power.

The building will be 55x120 feet on the ground, and will have three stories and a basement, built on classic lines and surmounted with a large dome on the north end of the building. At the apex of this dome will be a cupola of liberal proportions, with a balcony all around it. This will be reached by a stairway from the office floor. The dome will be covered with galvanized iron and brilliantly lighted with electric lights.



THE NEW SUBSTATION OF THE SEATTLE CATARACT COMPANY. From the architect's drawing.

The material used in the construction of the building will be a deep color red brick mortar, with Tenino sand stone trimmings.

The different floors are thus designed: The basement will be one large room, with a concrete and cement floor, where the blacksmith shop, work shop and general storage room will be located. The first floor, which is level with Seventh avenue, will be practically one large room, the full size of the building, with the exception of the entrance at the northeast corner of the building and the superintendent's office. This room will have a ceiling of 31 feet. There will be a concrete and cement floor over the entire surface of the machine room and a cement wainscoting 5 feet high all around the room. Above this the walls will be finished as on the outside, with deep red brick laid in black mortar. The trusses across this room, supporting the third floor of building, will be about 7 feet deep and all exposed from the floor below. Above the main entrance and superintendent's room on this floor will be two rooms set apart for sleeping rooms for men in charge of building. On this same level, across the north end of the large room, will be a liberal balcony, reached from the hall or landing of stairs, where visitors can look over the complicated machinery without any danger of coming in contact with it.

The third floor of the building will be devoted entirely to offices, having a president's and manager's room, secretary's room, large reception quarters, stenographer's room, and a large room for bookkeepers and accountants. The building will cost in the neighborhood of $80,000. Its architect is E. W. Houghton and Messrs. David Dow & Co. are the contractors. The construction work has already commenced and the foundation is well under way. It is expected that the power station will be ready for use by the end of this year.

The new substation of the Tacoma Cataract Company, which is also now under construction and located on the corner of Nineteenth and Commercial streets, will be one of the most substantial and ornamental buildings in the city of Tacoma. In addition to the classic architectural lines, which display the high art of the designer, the general effect will be very much embellished at night by the electrical effects in illumination. The building and equipment will cost the company in the neighborhood of $50,000 and will be one of the most attractive spots which visitors in the city may be shown. As with the Seattle building, the Tacoma substation will be built of concrete, red brick and Tenino sandstone. It will be 100 feet long and 50 feet wide and will have plenty of

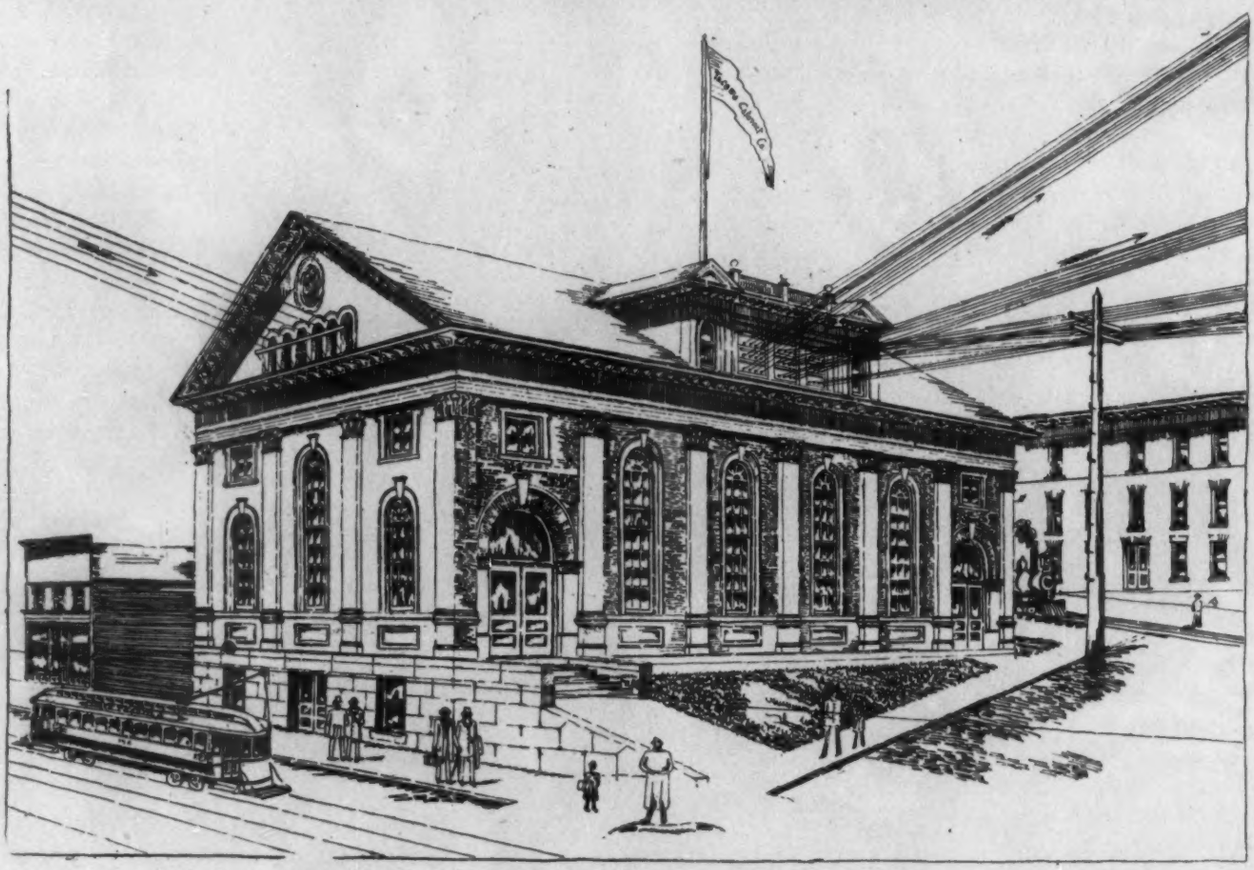
air space on the four sides of the building, thus affording complete ventilation and absolute immunity from a possible conflagration which, in another location, might possibly cripple the plant for weeks under such a contingency.

The basemet of the building is on a level with Commerce street and the machinery chamber itself is on a level with the grade of the Northern Pacific railway. The building, as the illustration shows, is well provided with doorways and windows. The basement will be occupied by a repair shop and will be used for general storage of supplies. The wires from the switchboard transformers will be on the ceiling of the basement and there will be no wires, therefore, exposed in the machinery room above, which will add to the neatness and safety of the arrangement.

The bricks will be laid in white mortar and pointed up both inside and outside the building. The building is designed on colonial classic lines and the pilasters, with corinthian capitals, will appear on the face of the walls supporting a stately cornice. The east gable was designed to receive the high tension power lines of the main transmission from Snoqualmie Falls. The distribution through the city, which will leave the building at low voltage, will be accommodated by the wide dormer window, shown on the north side of the roof. The east end of the building on the main floor will be occupied by the local office of the Tacoma Cataract Company. The rest of the main floor will be occupied by the transformers and switchboards, and any other machinery which it may be necessary to install.

The main machinery floor will be of concrete. There will be a travelling crane travelling the full length of the main room, which will be useful for handling heavy weights from one part of the building to another. The roof of the building will be planked and supported on substantial trusses and painted with asbestos paint, so as to be of slow burning construction. The outside of the roof will be sheeted with tin. The contractor, Mr. Chas. A. Sayre, expects to be able to turn over the building to the Cataract Company November 1st, of this year.

While these important changes are being made in the principal distributing systems of the Snoqualmie Falls Power Company, others equally important are in progress at the great generating station at Snoqualmie Falls. This installation was to have been a special point of interest in the recent journey of the late President McKinley through the western and north-western states, had not the serious illness of Mrs. McKinley in San Francisco interfered with the plans of the presidential party. Of all water power plants in existance this hydro-electric installation is undoubtedly one of the most interesting, as the recent Snoqualmie edition of THE JOURNAL attested. During the last six months it has been visited by engineers and capitalists from all over the world, who testify with high praise to the superior excellence of its operation under a most varied service that includes



THE NEW SUBSTATION OF THE TACOMA CATARACT COMPANY. From the architect's drawing.

electric traction, mill and factory power, as well as ordinary illumination. The entire load of the Snoqualmie system is operated in multiple and with a regulation of less than 2 per cent.

Two years have passed since the first current from Snoqualmie Falls was carried into the cities of Seattle and Tacoma, and in this short time the initial installation has proven too small. The capacity of the plant is to be enlarged to meet the increasing demand for power in these growing western cities. At the falls, distant forty-four miles in an air line from Tacoma and thirty-two miles from Seattle, are installed, in a rock-excavated chamber, four generating units, each consisting of a water wheel direct connected to a 2000-horsepower Westinghouse three-phase alternator. This transmission system, which is now generating, transmitting and distributing 8000 electrical horsepower, is to be more than doubled in capacity. At the same transmission voltage now employed, 30,000 volts, it is proposed to carry 12,000 horsepower more into the cities above mentioned, making a total output of 20,000 electrical horsepower. The electrical machinery is to be wholly furnished by the Westinghouse Electric & Manufacturing Company. The Abner Doble Company of San Francisco, which furnished the water wheel equipment for the initial installation, is figuring upon placing its wheels in the new extension, and, according to its plans, there will be a single wheel on each end of each generator shaft, and each wheel will be driven by a single jet of water 14 inches in diameter, the two jets combined being sufficient under the existing head of 270 feet to give the requisite power. The two water wheels and the generator between will be built on a single hollow shaft of oil tempered nickel steel.

The present underground generating station, which is 200 feet long, is to be lengthened out 150 feet up stream to make room for the new installation. A new penstock is to be built which will carry 50 per cent. more water than the old one. The transmission line that is to parallel the old line, will require 125 tons of aluminum wire, and the order for it has already been placed with the Pittsburg Reduction Company. The entire cost of these improvements will be in the neighborhood of $400,000. The work is to be vigorously prosecuted and it is expected that the first of the new generators will be delivering current into Seattle and Tacoma within the next eight months. The generating machinery will consist of three 3000-kilowatt rotating field generators of the two bearing type, generating a three-phase current at 1100 volts and 7200 alternations. The speed is to be 100 revolutions per minute. Each generator will require an exciting current of 320 amperes approximately, at 125 volts. For exciting these three generators a 200-kilowatt, eight-pole, direct-current generator of the two-bearing type is to be used. At 175 revolutions per minute it is to deliver under normal load a current of 1600 amperes at 125 volts.

The current which is generated at 1100 volts is to be raised to a line potential of 30,000 volts by nine 1000-kilowatt, oil-insulated, water-cooled transformers. These are to be delta-connected on both the primary and secondary sides. It is estimated that each transformer will weigh 11,000 pounds and require 500 gallons of oil. The switchboard that is to be installed is to consist of fourteen panels of white marble and is to be of the special type that was furnished for the original installation. Instead of the Niagara type, single-phase indicating wattmeter that is in use on the present switchboard, a polyphase, long scale indicating wattmeter is to be used. Where formerly a field plug switch was used, a double-pole field switch is to be employed. The standard equipment of synchronizing lamps is to be replaced by a single-pole plug switch mounted on the generating panel and connected to a synchroscope, which will be mounted on the multiplying panel. The increased capacity of the generators will necessitate placing three single-pole main switches, instead of one three-pole main switch. The circuit breakers, which are to be non-automatic, will be placed on an extension panel above the main instrument panel.

Each of the three generator panels is to be furnished with the following instruments: One 3000-ampere, non-automatic, double-pole circuit breaker, 1000 volts; three 3000-ampere, single-pole, double-throw main switches; three 3000-ampere, long scale alternating current ammeters; one 400-ampere, Westinghouse round pattern, dead beat, direct current ammeter for field circuit; one 400-ampere, double-pole, single throw, quick break, field switch, with shunt resistance and discharge attachment; three series transformers; two shunt transformers, with fuse blocks; one voltmeter plug switch receptacle; one synchronizing plug; one type "C" rheostat face plate and mounting for same; two pilot lamps, brackets and shades.

The exciter panel for the control of the 200-kilowatt compound wound machine, described above, will have mounted upon it the following apparatus: One 2500-ampere Weston, round pattern, direct current ammeter; one 2000-ampere, single-pole, adjustable jaw type circuit breaker; three 2000-ampere, single-pole, single-throw, main switches; one type "C" rheostat face plate and mounting for same; one voltmeter, plug and receptacle; one pilot lamp, bracket and shade.

The multiplying panel, which is to carry the necessary instruments for multiplying the duplicate sets of three-phase bus-bars, will be furnished with the following apparatus: One 3000-ampere, double-pole, non-automatic circuit breaker; three 3000-ampere, single-pole, single-throw multipling switches; one synchroscope; one three-pole, double-throw switch for throwing the above specified synchroscope onto either one of the three sets of two-phase bus-bars; one pilot lamp, bracket and shade; three shunt transformers.

For each group of three raising transformers there will be three switchboard panels similar to those at present installed in the generating station. Each of these panels will have mounted upon it the following apparatus: One 1500-ampere, single-pole, 1000-volt, automatic overload circuit breaker, with time limit relays; one 1600-ampere, long scale ammeter; one 1600-ampere, double-pole, double-

throw main switch; one series transformer; two pilot lamps, brackets and shades.

For each set of three panels, which controls a group of transformers, there will be needed one polyphase integrating wattmeter and two shunt transformers.

The Snoqualmie plant, when this increase is made, will have a capacity of 25,000 horsepower, and will, therefore, be the largest single water power plant in the United States outside of Niagara. All the electric street cars, all the municipal and domestic lighting, flour mills, machine shops, and industries where electric motors are employed in Seattle and Tacome, are run by the Snoqualmie plant, and effort is now being made to induce the company to extend its lines to Everett, Wash., to handle the paper mill and smelter there and to improve the local lighting service.

INDUSTRIAL GAS.—XXI.

BY FRANK H. BATES.

THE CALORIMETERY OF STEAM.

CALORIMETRIC processes for determining the *quality* of steam should properly be considered as those based upon actual heat measurements and not include methods depending upon other means, such as mechanical separation, etc.; however, since the term *calorimeter*, as applied to instruments for *steam quality determinations*, has been employed in practice to cover all forms, it will be so understood in this chapter.

Quality of steam. By this term is implied (1) The ratio of the total heat in a pound of the sample steam, less the heat required to raise a pound of water from 32°, at atmospheric pressure, to the boiling point of the given pressure—to the total latent heat, or, heat of vaporization, of one pound of dry steam at the same given pressure. This may be expressed as (2) the total heat in a pound of the sample, less the heat of the liquid, divided by the total latent heat of vaporization of one pound of dry steam at the same pressure. (3) For moist steam, or a mixture of wet and dry steam, the quality would equal the weight of dry steam in the mixture divided by the total weight of the mixture. (4) For superheated steam the quality expresses the weight of steam that would be kept dry and saturated by the heat contained in a pound of the sample of superheated steam. The heat of the liquid being neglected in both cases, this is equivalent to considering the quality as that weight of dry and saturated steam, the heat in which is equivalent to that in one pound of the superheated steam, neglecting the heat of the liquid in both cases.

Classification of calorimeters (Carpenter).

- Calorimeters
  - 1. Condensing
    - Jet
      - Barrel or tank
      - Continuous
    - Surface
      - Barrus' continuous
      - Hoadley's
      - Kent's Tank
  - 2. Superheating
    - External—Barrus' superheating
    - Internal—Peabody throttling
  - 3. Directly determining moisture
    - Separator
    - Chemical.

Of the 1st, or *condensing calorimeters*, there are but two classes—the *jet* and *surface*. In the former the steam mingles directly with the condensing water, whereas the latter condenses the steam within a coil or pipe and keeps it separate from the condensing water in which the coil or pipe is immersed.

Of the 2d, or *superheating calorimeters*, there are the *external* and *internal*. The former, Barrus' superheating, provides for carrying two separate steam lines from the steam main. The steam from one is superheated by heat applied externally, and is used to jacket the other line through which flows an equal weight of steam. The loss of heat by the first, and the gain by the second, afford a means for determining the quality.

Peabody's throttling calorimeter is an example of the internal. In this, heat, due to high pressure steam, is admitted to a chamber of a calorimeter containing steam of lower pressure, and in superheating the latter affords a means of determining the quality.

Of the 3d, or those *directly determining moisture*, there are the *separator* and *chemical* calorimeters.

The first mechanically separates the water from the sample of steam, while providing a means for ascertaining the amount of water removed, and the weight of the sample.

The second consists of apparatus for determining chemically the actual amount of water contained in a sample of steam. The method is based on the absorbtion of certain salts, soluble in the water, but insoluble in dry steam, and which, therefore, appear in the sample of steam in proportion to the amount of water present.

Choice of a calorimeter—comparative accuracy. For steam that is superheated or steam containing but a small amount of moisture the *throttling* is most accurate and results are more easily and quickly obtained. It can not be used when the sample of steam contains much moisture.

The *separating* calorimeter ranks second in accuracy and is not limited to steam containing little moisture. It can be used for superheated steam and results of equal accuracy to those obtained with the throttling calorimeter can be secured when carefully used; it is more serviceable, however, with wet steam. The accuracy of the remaining instruments is probably in the following order: *Barrus' superheating*, *Hoadley*, *continuous condensing chemical* and *barrel*.

Sampling the steam. In sampling the steam the main purpose is to secure a small quantity such as is required for testing, and which will fairly represent the average quality. By inserting a long, open end nipple (see figure 23) about halfway into the main steam line near the boiler, and where the issuing current is in a vertical direction, and continuing this nipple by felt covered pipe to the calorimeter, so as to avoid all pockets, will probably insure as good a sample as can be had.

Determination of the water equivalent of the calorimeter. In previous chapters in dealing with the calorimetry of fuel this topic has been discussed at more or less length, and it will be considered but briefly here. It is readily understood that it requires a certain quantity of heat to raise the substance comprising the calorimeter to the temperature of the liquid contained

within and this heat is abstracted from this liquid and must be accounted for. This is done by finding the *water equivalent*. This may be found by multiplying the weight of the calorimeter of given temperature by its specific heat, which gives the equivalent weight of water of equal temperature.

Letting k=water equivalent of the calorimeter;

W_c=weight of calorimeter;

s=specific heat calorimeter, then

$$k = s\,W_c.$$

The water equivalent may also be determined by its effect upon the temperature of a weighed quantity of water; for instance, pour a weighed quantity of water of

Fig 24.

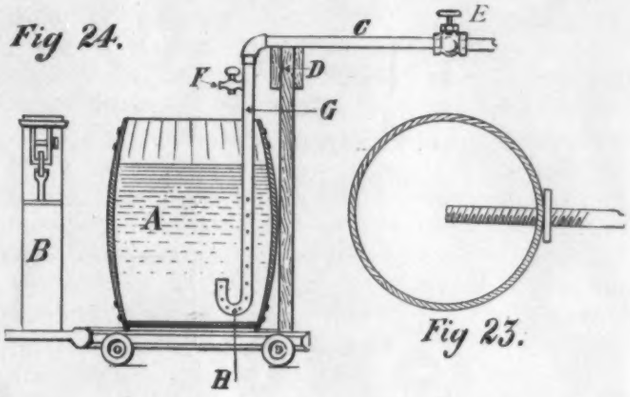


Fig 23.

known temperature into the calorimeter, the temperature of which is lower, and note the resulting temperature, thus—

Let k=the water equivalent of the calorimeter;

w=the weight of water;

t=the original temperature;

t_1=the resulting temperature;

then, since the heat has simply been transferred from one body to the other, without a change in actual quantity, we have $(w+k)\,t_1 = wt$, from which

$$k = \frac{wt}{t_1} - w = \frac{w(t-t_1)}{t_1}.$$

Other methods are applicable and should be used as *judgment* dictates.

There are many forms of calorimeters in practical use, but only a few representative types will be considered in the following descriptions:

The barrel calorimeter. This apparatus is only serviceable when approximate results will suffice. It is, however, quite commonly used. It will give, with the exercise of proper care, results whose error need not exceed 4 per cent.

Description. Steam from the boiler is led through a pipe directly into a measured quantity of water, contained in a barrel, and condensed.

For rough determinations all that is required is a *barrel, platform scale, thermometer* and *hose.* Preferably, however, a *barometer*, carefully calibrated, should be employed for obtaining the exact atmospheric pressure, to be added to the reading of a finely graduated *steam gage*; the thermometer should be graduated to not less than tenths; the scales used should also be finely graduated and accurate; and, as with fuel calorimeters, agitators for bringing the water to an even temperature should be employed. Furthermore, the barrel may be covered with heat-retaining material, or made double and packed with same, to lessen the radiation of heat.

Operation. The steam pressure by gage is first noted and readings therefrom taken at regular intervals throughout the test. A barrel A (figure 24) capable of holding some 450 pounds of water is placed on a platform scale B. Pour approximately 360 pounds of water into the barrel and pass steam from the boiler in through the tube or pipe C into the water, until the temperature of the latter rises to 130° Fahrenheit. This serves to warm up the barrel. Throw out the water and weigh the empty barrel, and quickly put in exactly 360 pounds of water, taking the temperature of same immediately. Hold the hose or pipe away from the barrel for a minute, blow steam through to heat and dry it thoroughly. Suspend the hose or pipe on the bracket D, so as not to make contact with the barrel, open the valve E, admitting steam to the hose and water. If a stirrer is employed, the water should be well agitated. The temperature shoud be carefully noted until it rises to 110° Fahrenheit, when the steam should be turned off and the air cock F opened, permitting the water within and without the hose to come to a common level. Weigh the barrel with the water and condensed steam, without disturbing the hose—then weigh with the hose out, in order that corrections may be made for the displacement due to the hose.

Derivation of results. Having the weight of the condensing water in the barrel, the weight of the steam admitted, the temperatures of the water in the barrel, both before and after admitting the steam, and the pressure of steam by gage, the quality of the steam is easily calculated by simple substitution in the following formula:*

$$Q = \frac{d}{w} = \frac{1}{l}\left[\frac{W+k}{w}(t_2-t_1) - (t-t_2)\right] \qquad (1)$$

in which

Q=quality of steam=percentage by weight of pure, dry steam in the sample steam;

d=weight of dry steam in the sample steam;

W=weight of condensing water=weight of water in the barrel before steam is added;

w=weight of sample=weight of steam and water brought over to the barrel and condensed;

t=temperature of steam at the pressure of test (This temperature may be found in tables of properties of steam);

t_1=initial temperature of the condensing water (cold);

t_2=final temperature of condensing water (warm);

l=total latent heat of steam at pressure of test (may be found in tables of properties of steam);

k=the water equivalent of the calorimeter.

Formula (1) is derived as follows:

Each pound of dry steam gives up its latent heat in changing from a vapor to a liquid. Since there are *l* heat

*All temperatures to be in degrees Fahrenheit; d, W, and w to be in pounds.

units (B. T. u.) per pound, then for d pounds there would be dl heat units.

The w pounds of steam and entrained water condensed becomes lowered in temperature from t degrees (the temperature of steam at the observed pressure) to t_2 degrees (the final temperature of the condensing water), hence the total number of heat units given to the condensing water is equal to

$$d\,l+w\,(t-t_2). \qquad (a)$$

Further: the W pounds of water originally in the barrel is raised in temperature from t_1 to t_2 degrees, or the total number of heat units received may be expressed or

$$W\,(t_2-t_1). \qquad (b)$$

It is evident that the heat received must equal the heat given, hence expression a equals expression b, or

$$d\,l+w(t-t_2)=W(t_2-t_1) \qquad (c)$$

from which the value of d may be readily equated as

$$d=\frac{W\,(t_2-t_1)-w\,(t-t_2)}{l}$$

and corrected for the effect of the barrel or condensing tank

$$d=\frac{W+k(t_2-t_1)-w(t-t_2)}{l.}$$

Since the weight of any steam (d) multiplied by 100 and divided by the sum of the weights of both dry steam and entrained moisture (w) of the sample gives the percentage of dry steam in the sample, which is the quality

$$Q=\frac{d(100)}{w}=\frac{100}{l}\left(\frac{W+k}{w}(t_2-t_1)-(t-t_2)\right)$$

Barrus' throttling calorimeter. The following description of a form of throttling calorimeter, designed by Geo. H. Barrus of Boston, is taken from the Babcock & Wilcox Co.'s publication, "*Steam*":

Steam is taken from a ½-inch pipe provided with a valve and passes through two ¾-inch tees situated on opposite sides of a ¾-inch flange union, substantially as shown in the accompanying sketch. A thermometer cup, or well, is screwed into each of these tees, and a piece of sheet iron perforated with a ⅛-inch hole in the center is inserted between the flanges and made tight with rubber or asbestos gaskets, which also act as non-conductors of heat. For convenience a union is placed near the valve as shown, and the exhaust steam may be led away by a *short* 1¼-inch pipe, shown by dotted lines. The thermometer wells are filled with mercury or heavy cylinder oil, and the whole instrument from the steam main to the 1¼-inch pipe is well covered with hair felt.

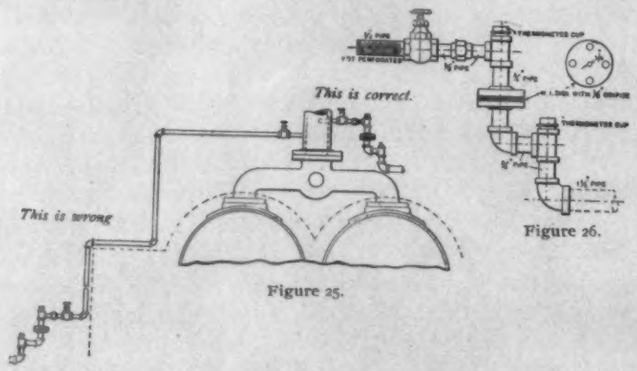


Figure 25.

Figure 26.

Great care must be taken that the ⅛-inch orifice does not become choked with dirt, and that no leaks occur, especially at the sheet iron disc, also that the exhaust pipe does not produce any back pressure below the flange. Place a thermometer in each cup, and, opening the ½-inch valve wide, let steam flow through the instrument for ten or fifteen minutes; then take frequent readings on the two thermometers and the boiler gauge, say at intervals of one minute.

The throttling calorimeter depends on the principle that dry steam when expanded from a higher to a lower pressure without doing external work becomes superheated, the amount of superheat depending on the two pressures. If, however, some moisture be present in the steam, this must necessarily be first evaporated, and the superheating will be proportionately less. The limit of the instrument is reached when the moisture present is sufficient to prevent any superheating.

Assuming that there is no back pressure in the exhaust, and that there is no loss of heat in passing through the instrument, the total heat in the mixture of steam and moisture before throttling, and in the superheated steam after throttling, will be the same, and will be expressed by the equation

$$H-\frac{xL}{100}=1146.6+.48\,(t-212)$$

$$\text{or } x=\frac{H-1146.6-.48(t-212)}{L}\times 100$$

in which x=percentage of moisture; H=total heat above 32° in the steam at boiler pressure; L=latent heat in the steam at boiler pressure; 1146.6=total heat in the steam at atmospheric pressure; t=temperature shown by lower thermometer of calorimeter; 212=temperature of dry steam at atmospheric pressure.

Theoretically the boiler pressure is indicated by the temperature of the upper thermometer, but owing to radiation, etc., it is usually too low, and it is better to use the readings of the boiler gauge, if correct, or better still to have a test gauge connected on the ½-inch pipe supplying the calorimeter.

If the instrument be well covered, and there is as little radiating surface as possible, the above assumption that there is no loss of heat in passing through the instrument may be nearly, though never quite, correct. On the other hand it is more than likely to be very far from correct, and, to eliminate any errors of this kind, Mr. Barrus recommends a so-called "calibration" for dry steam. This, again, involves an assumption which is open to some doubt, which is that steam, when in a quiescent state, drops all its moisture and becomes dry. No other practical method, however, has been proposed, and this is, therefore, the only method used at the present time. Some engineers, however, refuse to make any calibration, but, instead, make an assumed allowance for error.

To make the calibration close the boiler stop valve, which must be on the steam pipe beyond the calorimeter

connection. Keep the steam pressure exactly the same as the average pressure during the test, for at least fifteen minutes, taking readings from the two thermometers during the last five minutes. The upper thermometer should read precisely the same as during the test, and the lower thermometer should show a higher temperature; this reading of the *lower* thermometer is the calibration reading for dry steam, which we will call T.

Calculation of results, allowing for radiation, by calibration method:

$$\text{Formula } x=\frac{.48(T-t)}{L}\times 100$$

in which x=percentage of moisture; T=calibration reading of lower thermometer; t=test reading of lower thermometer; L=latent heat of steam at boiler pressure.

The method of taking a sample of steam from the main is of the greatest importance, and more erroneous results are due to improper connections than to any other cause. The sample should be taken from the main steam current of the steam ascending in a vertical pipe. Avoid perforated and slotted nipples, and use only a plain, open end nipple projecting far enough into the steam pipe to avoid collecting any condensation that may be on the sides of the pipe. Take care that no pockets exist in the steam main near the calorimeter in which condensation can collect and run down into sampling nipple. Make connections as short as possible.

As mentioned above, there is a limit in the range of the throttling calorimeter which varies from 2.88 per cent. at fifty pounds pressure to 7.17 per cent. at 250 pounds. When this limit is reached a small separator may be interposed between the steam main and the calorimeter, which will take out the excesses of moisture. By weighing the drip from the separator and ascertaining its percentage of the steam flowing through, and adding this to the percentage of moisture then shown by the throttling calorimeter, the total moisture in the steam may be ascertained. It is seldom, however, in a well designed boiler that any but a throttling calorimeter becomes necessary.

*Carpenter's Separating Calorimeter.** The instrument may be described as follows: It consists of two vessels, (see figure 27) one being interior to the other; the outer vessel surrounds the interior one so as to leave a space which answers for a steam jacket; the interior vessel is provided with a water gauge-glass 10, and a graduated scale 12. The sample of steam the quality of which is to be determined is supplied through the pipe 6 into the upper portion of the interior vessel. The water in the steam is thrown downward into the cup 14 together with more or less of the steam, the course of the steam and water is then changed through an angle of nearly 180 degrees, which causes the greater weight of water to be thrown outward through the meshes in the cup into the space 3 below in the inner chamber. The cup serves to prevent the current of steam from taking up any moisture which has already been thrown out by the force of inertia. The meshes or fins project upward into the inside of the cup, so that any water intercepted will drip into the chamber 3, the steam then passes upward and enters the top of the outside chamber. It is discharged from the outside chamber through an orifice 8, of known area, in the bottom part, which is much smaller than any section of the passages through the Calorimeter, so that the steam in the outer chamber suffers no sensible reduction in pressure by passing through the calorimeter. The pressure in the outer chamber being the same as in the interior, has the same temperature and consequently no loss by radiation can take place from the interior chamber except that which takes place from the exposed surface of the gauge-glass. The pressure in the outer chamber and also the flow of steam in a given time is shown by suitably engraved scales on the attached gauge. The scale for showing the flow of steam is the outer one on the gauge, and is graduated by trial, and gives the weight which is discharged in ten minutes of time.

By what is commonly known as Napier's law, the flow of steam through an orifice from a higher to a lower pressure is proportional to the absolute steam pressure until the pressure against which the flow takes place equals or exceeds .6 of that in the vessel under pressure. The accuracy of this law has been discussed in a paper by Prof. Peabody, Vol. XI., page 187, *Transactions*, and it has also been tested by experiments in Sibley College. The experiments in both cases indicate its substantial accuracy. The reading of the pressure gauge is proportional to pressures above the atmosphere, and hence the calibration curve will not give results proportional to gauge readings, and furthermore there will be a slight correction due to change in barometer reading. This latter correction is, however, exceedingly small, and will never make any sensible error in results. Thus a change in barometer of 1 inch would increase or diminish results by only one 230th part when the steam pressure is 100 pounds. This would seldom make one hundredth of 1 per cent. difference in the results. The values of the calibrations on the gauge can readily be verified by condensing the discharge steam for a given period of time.

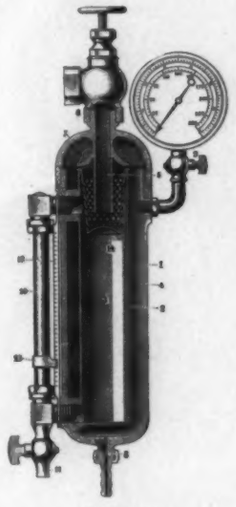


Figure 27.

The graduations of the scale 12, attached to the inner vessel, show, when the idex is set properly, the weight of water in pounds and hundredths which has been separated from the steam. This scale is graduated by actual calibration with water at a temperature of 100 degrees, and corrected for a coefficient of expansion so as to be as nearly as possible correct for water at a temperature corresponding to a steam pressure of 100 pounds. This correction is, however, a very small amount and of no practical importance, as it would seldom affect the results by even one-hundredth of 1 per cent. The percentage of

*From a paper presented at the St. Louis meeting (May, 1896) of the American Society of Mechanical Engineers.

moisture in the steam is found by dividing the weight of water, as shown on the water gauge attached to the inner vessel, by the sum of this quantity and that shown on the flow-gauge 9; the quality or percentage of dry steam is obtained by dividing the difference of the readings by the sum.

In the use of the instrument the outer vessel and connected pipe through which the sample is obtained should be carefully clothed to prevent unnecessary loss of heat by radiation.

The total size of the instrument is about 10x2½ inches, and its weight about six pounds, so that it is in convenient form and portable.

TABLE GIVING RESULTS OF EXAMINATION OF QUALITY OF STEAM DISCHARGED FROM INNER TO OUTER VESSEL.

Determination of Quality with Separating Calorimeter.					Determination of Quality of Steam Discharged by Separating Calorimeter with Throttling Calorimeter.		
Duration Run, Minutes.	Gauge Pressure, Pounds.	Pounds Separated Water in Run.	Pounds Condensed Steam in Run	Quality Steam Per cent	Temperature in Calorimeter	Quality Steam in exhaust from Separating Calorimeter.	No of Observations.
25	81 5	1.15	4 45	79 46	281.	99.95	6
25	78.2	0 15	5.20	97.2	281 3	100.00	6
25	80.8	0 525	4.25	89.005	286 5	100.00	6
25	79.5	0.150	4 75	96 94	281 8	99.95	6
25	78 5	0 300	5 000	94 34	282 8	100 00	6
25	77.6	0.150	5.45	97 32	282.3	100 00	6
24	79.5	1.8	4 55	71 65	280 1	99 94	6
24	78.5	1 4	4.90	77 77	279 5	99 9	6
20	83.5	1 15	4.1	77 67	286 5	100.00	5
20	81.6	1 70	4.75	73 64	282 7	99 98	5
20	74 8	0.65	3.95	85 87	283 7	100 05	5
20	82 0	0 85	3.95	82.29	286 8	100 05	5
20	82.6	0.35	4.15	92 22	285 6	100.0	5
20	81 5	0.20	3.95	95 15	285.2	100 05	5
20	81.4	2.20	4.325	66 28	283.1	100.0	5
20	80.3	0.30	4.55	93 81	282.8	100.0	5
20	82.0	0 20	4 65	95.8	282.8	99 98	5
20	81 1	0.20	4 40	95.7	284 0	100.0	5

The accuracy of the instrument depends first, on the accuracy of the scales, both of which can be readily verified by experiment; second, upon the complete separation of the water from the steam by the separator. This was tested by a large number of experiments by discharging the steam from the outer vessel through a throttling calorimeter. Nearly one hundred observations were made, the average results of which, as given in the above table, show the exhaust steam in the conditions tested to have a quality of 99.998 per cent. As it is certain that some loss of heat occurred between the two instruments, it is believed that we can consider with confidence the steam as passing from the inner into the outer vessel perfectly dry and saturated.

It is also true that a considerable error in the weight of steam discharged will effect the results but very little, since in every practical case the moisture is a small percentage of the total. Thus supposing the results of our examination show 5 per cent. moisture, but that an error in the weight of the steam discharged of 5 per cent. has been made. In that case the correction to our result should be but .05 or $\frac{1}{20}$ of the results obtained, in this case amounting to ¼ of 1 per cent. The above is an extreme case and is several times greater than any that is likely to occur, as shown by the results of various tests quoted.

Third, the loss by radiation in the exposed portions of the water glass. This surface is a very small portion of the whole surface and the loss by radiation is always an exceedingly small amount. We have made a number of experiments in Sibley College to determine this amount and have considered that in every case it affected the results less than errors of observation. We have tested this quantity by comparing the instrument with a throttling calorimeter, taking steam of essentially the same quality and the difference has always been a very small fraction of 1 per cent. Professor W. C. Unwin, in a paper before the Institution of Civil Engineers on the determination of the dryness of steam, also gives tests of this instrument as compared with a throttling instrument and considers that the results in every case practically confirm each other. It could, if essential, be tested by passing dry steam through the instrument.

An instrument somewhat like that described above has been in use some years in connection with a graduated condensing can, as shown in figure 28, for receiving steam discharged from the outer chamber. This has proved a very serviceable instrument, but not as portable nor as convenient to use as the form described in this paper.

The question has recently been raised regarding the value of calorimetric determinations from the fact that great difficulty is experienced in obtaining a sample of steam which fairly represents the average in the steam pipe. This great variation of samples of steam was pointed out in a paper "Notes regarding calorimeters," Vol. XII., page 827, *Transactions*, and numerous experiments were cited showing great variation. Valuable information has also been laid before the Society, by papers, at the Detroit meeting, by Professor Jacobus, and at the last meeting in New York, by Professor Denton. The writer believes, from occasional expressions seen in the technical press, that there is a tendency to extend the application of the conclusions drawn from the experiments to a greater field than the experiments would warrant or the authors desire. The laboratories of Sibley College have also been engaged in the further investigation of this subject, and while these investigations are not concluded, the writer feels that the following conclusions are justified, and may in a certain measure serve to guide calorimetry practice.

They may be briefly stated as follows: First, the steam ordinarily discharged from a boiler of proper proportion and in good working condition carries an exceedingly small percentage of water. Second, a certain amount of water will be carried along by the steam in the form of vapor or small drops, that this amount varies somewhat with the velocity, but probably does not exceed 2 or 3 per cent. by weight, and furthermore, a fair sample of such steam is usually obtained by any of the ordinary methods in use. Third, water is sometimes thrown from the boiler in large amounts, and in such a case it will usually remain distinct from the steam and will pass along the bottom of horizontal pipes in a stream of greater or less depth, and will flow, if moving downward, in a vertical pipe in irregular positions, depending upon its velocity and various other considerations. Steam carry-

ing water in this way, when ascending a vertical pipe, will probably be irregularly charged, and samples drawn from time to time are likely to vary greatly. This condition can usually be considered an abnormal one, and probably cannot be fairly sampled by any method. In case large amounts of water are thrown over, the quality of the steam cannot be even approximately obtained without the use of a steam separator for removing the

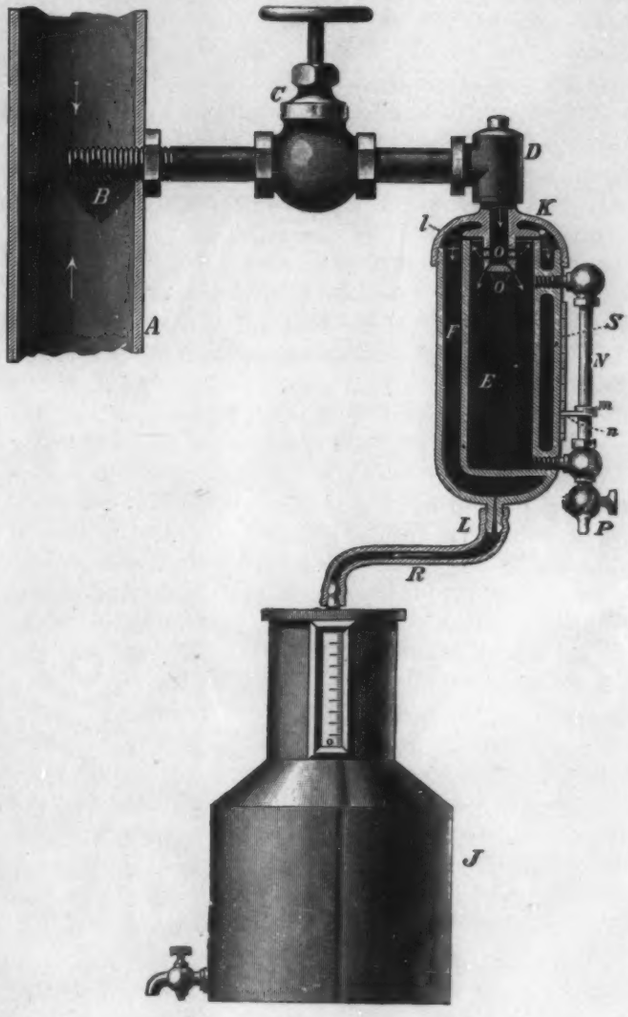


FIGURE 28.

excess of water. Fourth, steam, even in a very dry condition, is likely to deposit a film of water on the inside of the pipe by condensation. This amount is rarely of sufficient importance to greatly effect the results, but if the calorimeter is so located as to draw this directly into the pipe it may show very wet steam when the contrary condition actually exists.

The writer believes that samples for calorimetric determination should be drawn from a vertical pipe in which there is an ascending current of steam, and that the sample should be taken as uniformly as possible from all sections of the pipe, except that no steam should be drawn immediately adjacent the exterior portion of the pipe, and in such a case the results will indicate, if substantially uniform in all cases not showing an excessive amount of moisture, *the average quality of the steam within reasonable limits of errors of observation.*

Further, if the determinations obtained by the calorimeter in this position are irregular or show large percentages or error, it may be reasonably doubted that the sample of steam obtained is accurate.

Fifth, a steam separator is always desirable to remove excess of water from the main steam pipe, in which case determinations should be taken after the steam has passed the separator. The writer, however, believes from his own experience that the use of the separator will not be found essential in one case out of twenty, for the reason that water is very rarely thrown into the steam in larger quantities than the steam itself will take up and retain in a uniformly distributed condition.

Steam Separating Calorimeter. General method of using the steam separating calorimeter is briefly as follows:

First. Attach the instrument to a pipe leading to the main steam pipe, as already explained, so as to obtain the fairest sample of steam.

Second. Wrap the instrument and connections thoroughly with hair felt, to prevent loss of heat by radiation, leaving only the scales visible.

Third. Permit the steam to blow through the instrument until it is thoroughly heated before making observations.

Fourth. Make the initial and final readings on the scale 12 at beginning and end of a period of ten minutes of time, and note the average position of the hand on the gauge dial during this time. The pressure should be kept as nearly constant as possible during the period of discharge, in which case this hand will remain constant.

Fifth. Compute the percentage of moisture as explained by dividing the reading on the scale 12 by the sum of the readings on scale 12 and the gauge dial.

The Chemical Calorimeter. Certain salts are not absorbed by dry steam though soluble in water. If such salt is dissolved in the water of the boiler, a sample of the steam will show traces in proportion to the entrained moisture.

Operation. Add three ounces of common salt to the water in the boiler. Draw off a sample of the solution, at the same time securing a sample of equal weight of steam, condensing in a separate vessel. Add to each an equal quantity of chromate of potash (a few drops from a pipette); also treat a quantity of distilled water equal in weight to the samples of water and steam, with the same quantity of the chromate of potash.

Now take 100 cubic centimeters of each sample (water, steam and distilled water), which has been treated with the potash, and drop from a solution of silver nitrate of 10.8 grams of silver to the liter, by a single drop at a time (by means of a graduated pipette), into the three samples of 100 cubic centimeters. Chloride of silver forms, and at the instant the chloride has all been precipitated the color of the liquids change from a milky color to a red. The amount of nitrate of silver required in each case is indicative of the weight of salt in same and affords a means of determining the moisture.

By dividing the difference in cubic centimeters between the amount of silver nitrate required by the sample of condensed steam, and the sample of distilled water by the difference between the cubic centimeters of silver nitrate required by the sample of boiler water and the sample of distilled water, we get the amount of moisture.

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EDITORIAL.

AVAUNT THE WAIL "WOLF! WOLF!"

Through its connections with the system of the Standard Electric Company, power from the Colgate powerhouse of the Bay Counties Power Company is now distributed in every-day, hard, commercial service at a distance in excess of two hundred miles from its point of generation. And the manager of the local company which is making its distribution—himself one of the most exacting electric lighting and power managers in the West—after having sufficient experience to satisfy himself, states: "I want no better power; it's good enough for me."

There was a time, not so very many years ago, when a transmission of two hundred miles was considered as being beyond the pale of commercial feasibility, and there was also a time, not so very many months ago seemingly, when it was said that such a transmission, if attained, would be beset with such technical and engineering difficulties as to relegate it into the category of experimentalism. Now the fact has been demonstrated that all fears of either nature are groundless.

Back several years ago, before California transmission enterprises had struggled their way into eminence, a certain financier who had to do with a transmission project of moderate proportions, was so battle-doored-and-shuttle-cocked by the conflicting electrical opinions thrust upon him, that finally he began to believe the possibility of electrical transmission to be a myth. At last a sales agent of a prominent electrical manufacturing company came along, and without entering upon *pros* and *cons*, gave satisfactory guarantees that his company would accomplish certain results at a stated cost under prescribed conditions. The sales agent got the contract, his company fulfilled its agreement, and certain prophets along electrical lines went down in ignominy and falsity. Then, in his resentment, did the financial man think to himself, "All men do not speak the truth, and electrical folks are men." And so, when a newer and vaster enterprise of momentous nature came his way, he cast electrical vagaries to the winds, lest they prove false, and in building his enterprise upon commercial limitations, leaving engineering problems as secondary and to be worked out along the lines of natural development—in doing this he builded well. Thus it is that the transmissions of California lead the world in more senses than one.

If it be regarded from an engineering standpoint purely, it is not an unmixed blessing that circumstances have compelled the temporary tying-in of the Standard and Bay Counties systems. Let us, even at the risk of repetition, review the situation which is giving us a phenominal transmission line of over 200 miles in length. From Colgate to Oakland the distance, by way of the Bay Counties' line, is 142 miles. From Oakland to Redwood City, by way of the Standard Electric Company's line, is 49 miles, hence the distance from Colgate to Redwood City is 191 miles. From Redwood City the Bay Counties' power is continued, by means of the secondary distribution of the Consolidated Light and Power Company, northerly along the peninsular of San Francisco to Burlingame for a further distance of 11 miles, making the total length of line from Colgate to Burlingame to be 202 miles. And during November of the present year, the Standard Company's high tension line will be completed into the Eighth-street substation of the Standard Electric Company, in the city of San Francisco, some 20 miles further than Burlingame, and when this is done, the Standard Electrical Distribution Company will have at its disposal, for use in San Francisco, electrical energy developed on the Yuba river, 222 miles distant. This extraordinarily long transmission will exist until early in January next, when it is stated that the Standard Company's great station at Electra, in Amador county, will be placed in service.

From Oakland, where the Bay Counties' line ends, power is taken *backward*, so to speak, over the Standard Company's line to Mission San Jose, which is the company's main switching station, 26¼ miles distant from Oakland. Back again over the Standard line from Mission San Jose to Stockton is a further stretch of 49.6 miles, hence the Standard line from Oakland to Stockton has a length of 75.85 miles which, added to the length of the Bay Counties' line from Colgate to Oakland, gives a transmission that is 218 miles in length. This line has already been placed in commercial service and is delivering 1000 horsepower to the Sperry Mills the Stockton Gas and Electric Company and other industries of Stockton. What a glorious experiment it would be to take Bay Counties' power on from Stockton over the 46 miles of completed Standard line intervening between Stockton and the Standard plant at Electra? This would give an uninterrupted or straight high tension circuit of 264 miles from Colgate to Electra, and the presence of the great

2000-kilowatt generators at either end would enable the engineers of the companies to perform experiments of lasting and far reaching value.

The experience of the four months which have passed since the inauguration of the extreme long distance transmission service from Colgate was begun, is that no further question need be raised concerning the reliability of the service. This does not mean that transmission service is to be regarded as infallible, for infallibility is not a human attribute, but it does mean that the experience of the last four months has demonstrated, in so far as four months' experience will demonstrate anything, that extremely long distance high tension transmission service is possessed of no materially great hazard because of its exceptionally long lines or because of its exceptionally high potential. In fact, there is room for the contention that the qualifying adverb "materially" is unnecessary to the truthfulness of the statement, for with a powerhouse as perfect as the central station of any city, and with every function of the equipment in duplicate even to the poleline, it seems justifiable to contend that such plants are surrounded with every safeguard known to the highest class of modern electric service. Everything, however, depends upon the thoroughness of the line patrol, and this is a point which has by no means escaped the vigilance of Mr. L. M. Hancock, general superintendent of the Bay Counties Power Company, whose splendid organization for the patrol of the hundreds of miles of lines of the system is in a great measure responsible for the remarkable success achieved.

For times without number these columns have reminded the engineering and financial worlds that with the advances made in electrical science the distance of feasible electrical transmission will ever go onward as the voltage values go upward. Eight years ago the lines of the old Pomona plant, which carried 10,000 volts, were viewed with awe and almost reverence. Now the use of 40,000 volts is becoming commonplace in California at least, and another six months will see hundreds of miles of transmission lines in the Golden State operated at a potential of 60,000 volts. Indeed, the Standard Electric Company has already operated one of its lines experimentally in adverse weather for over two hours at the extreme potential of 80,000 volts, and this without experiencing any trouble whatever. Where is there a man who has the hardihood to predict where the commercial limitations of electric transmission will ultimately rest? In truth, the possibilities of electrical transmission development are seemingly illimitable.

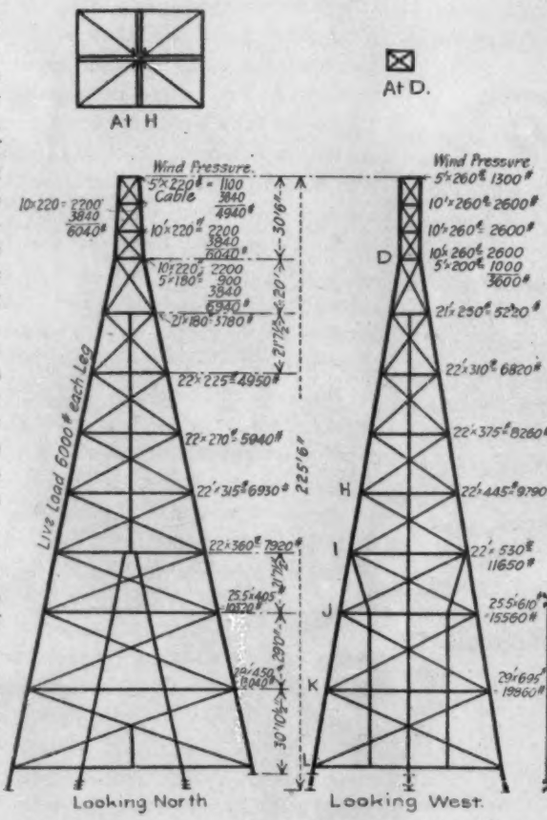
Steam engines, waterfalls, wind, wave and solar engines, as well as all devices utilized in the production of mechanical energy are subservient of the genie of electrical transmission, and even the seemingly fanciful bears possibility of being eventually, though remotely, a factor in its onward development. For instance, Prof. T. C. Mendenhall, in discussing "Power from Terrestial Heat," in a current number of *Cassier's Magazine*, points out that in the stored energy of the heat of the earth's interior is beyond power of calculation, and some not entirely unsuccessful attempts to utilize this have already been made. For a short distance below the surface the temperature increases downwards at an average rate which indicates that at a depth of fifty miles it is not less than 5000° Fahr., and there is abundant reason for believing that the earth is an intensely hot body with only a thin layer of poorly conducting cold surface matter. These are the essential conditions of a heat engine of enormous capacity, and as in many parts of the world comparatively high temperatures are found very near the surface, while in all parts considerable ranges are possible within reasonable differences of level, the interior heat of the earth, which has an origin more remote in time than the sun, or its own axial rotation, is worthy of most serious consideration as a possible and reasonable source of power. Its importance will be greatly enhanced when we are able to transform heat energy directly into electricity, on a large scale and with economy, avoiding the great waste which necessarily accompanies the use of the steam engine—"and this must soon come about," adds Professor Mendenhall. And when it does come about, as come it will, another fanciful possibility will have become realized into a practical reality to the further glorification of the transmission industry.

But coming nearer home, the possibilities for electrical transmission development are literally on every hand. Central California and southern California are each interwoven with networks of transmission lines which are respectively unified into a common system, so far as ownership or control are concerned. Northern California is making remarkable progress toward the development of its waterpowers for industrial and mining uses, but its transmissions, together with those of the great San Joaquin Valley, have not developed sufficiently as yet to realize that community of interest which ends in consolidation and expansion. Even the cities of Puget Sound, where fuel is exceedingly cheap, are deriving the bulk of their electric power from electrical transmission, and the great garden spot of southern California, the home of crude oil in the West, similarly finds that its pumping and its manufacturing, its railways, its lighting and its almost every industry, are performed best and cheapest when the service is rendered from a power transmission source. Oregon, Washington, Utah and Montana are all in line with important electrical transmissions, and now comes Arizona which, in claming statehood, shows mining and eleetrical developments of extraordinary interest and importance. Indeed, the era of transmission development has only begun—and it will never end.

Thus is experience laying bogyism in its grave, and the darkness of fear and trepidation born of ignorance is day by day giving away before the light of the knowledge derived from the truly herculean transmissions of the West.

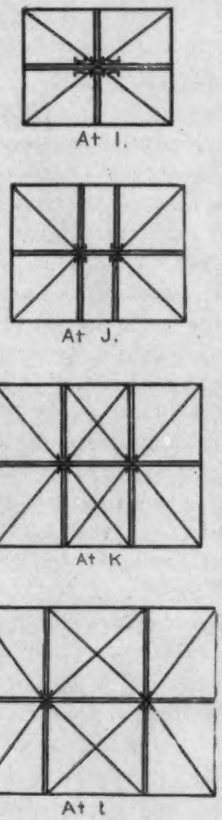
SOME FURTHER DETAILS OF THE CARQUINEZ SPAN.

IN response to requests for more explicit data concerning the mechanical features of the towers of the great Carquinez span of the Bay Counties Power Company, it may be reiterated that the cables are stretched across the towers from anchor to anchor, from all of which they are insulated, and the land conductors are direct-connected with them near each end. The cables consist of nineteen single-strand wires, weigh one and six-tenths pounds per lineal foot, and have a total breaking strength of 96,000 pounds, the unit breaking stress of the material being about 200,000 pounds per square inch. The wires had three coats of oil. Supporting nothing but themselves, each cable takes the form of a catenary, which has a half-span of 1972 feet, and a deflection of 147 feet, measured from the main tower, and a half-span of 2455 feet and a deflection of 227 feet, measured from the south tower. On this basis each cable would have a tensile load at the main tower of 21840 pounds, and at the south tower of 22,000 pounds. Experiments were made of the effect of the wind pressure, and the conclusion was reached that it might, in extreme cases, double the calculated strains, and the cables were considered amply safe for this. It has been found since that wind pressure will not strain the cables as much as assumed, as practically no shocks due to undulations will occur—simply a static pressure, due to a certain lateral deflection of the cables under heavy winds. It has been found that even in a gale the cables remain practically stationary at a certain lateral deflection, due to the wind, and that the wind does not produce undulations as had been expected.



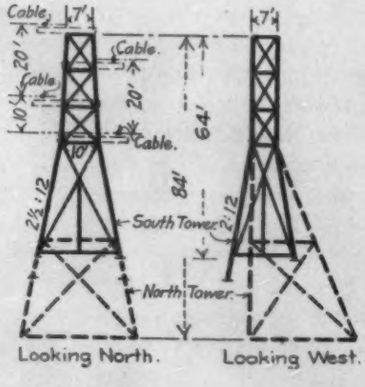
STRESS DIAGRAM OF MAIN TOWER.

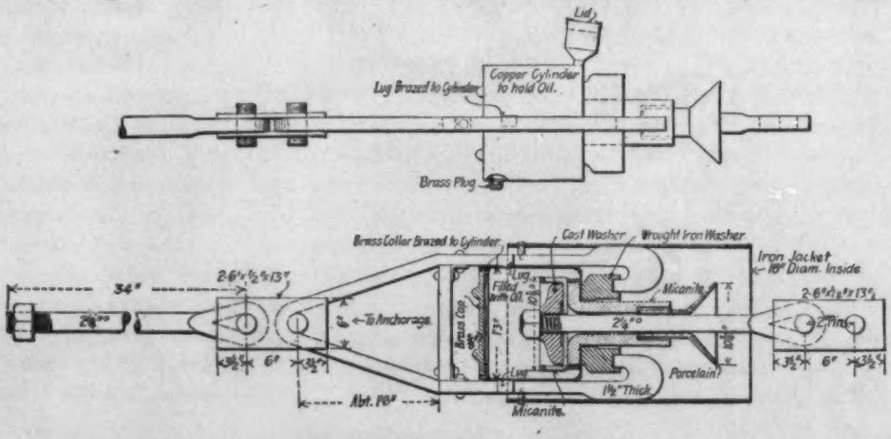
TOWER DIAGRAMS.



The towers are, as these columns have stated heretofore, of iron and steel throughout, except cross arms for carrying the cable saddles. The main tower is 225½ feet in extreme height from the foot of the lowest column, and has a base about 68x90 feet. The four main posts are each made of two 12-inch channels, battered in both directions, the center distances of 9½x6½ feet at a point 30½ feet below the top, above which they batter in one direction only to a top width of 6½ feet both ways. The channels in the columns vary in size from 12-inch 30 pounds at the base (reinforced by one 5x3-inch angle in each lower section), where they sustain a maximum compression of 132,510 pounds in each column, to 5-inch 6¼ pounds at the top, where they have 5300 pounds compression in each column. The design was made to fit material on hand, as time was limited.

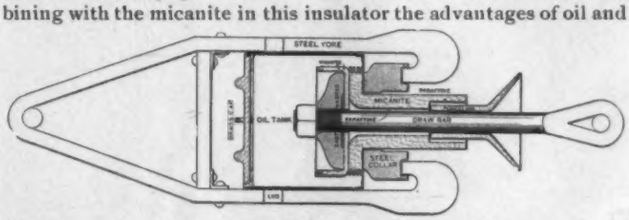
The pyramidal part of the tower is divided into stories from 20 feet high at the top to about 38 feet high at the bottom, braced with horizontal and diagonal struts in each face, as shown in the diagram. These struts are all made of four angles from 3x2 inches to 2x2 inches, pairs of them being latticed together with their flanges about 8 inches apart and their webs turned out from the center of the strut. Where these struts intersect, one of them is continuous and has a connection plate on each flange and the other one is cut to clear and riveted to each plate. These struts are connected to the columns by pairs of plates shop-riveted to the flanges and webs of the latter. On the opposite transverse faces of the tower and in a parallel vertical plane, midway between them, there is a pair of intermediate battered columns each composed of four 2x3-inch and 2x2-inch angles reaching to the fourth story, above which there is a single center column of four 2x2-inch angles reaching four stories higher. In each longitudinal face of the tower there is a similar center column seven stories high, and in all of them the two pairs of angles are latticed together with their flanges 8 inches apart, back to back, so as to pass through the horizontal and diagonal struts and be riveted to their flanges at intersections. The other vertical and inclined members in the





lower stories of the tower are simply pairs of small suspension angles to support the centers of the long horizontal members. The main columns are spliced with flange and web plates just above the horizontal struts; all members were shipped separately and field riveted at intersections and connections. The main columns are anchored to crossed 4-inch I-beams in the bottom of the concrete blocks; the other columns are anchored with long bolts and washers built in the concrete. At every story the tower has ⅞-inch to 1⅛-inch horizontal lateral diagonal rods which are pin connected to angles riveted to the columns and to extensions of the tie plates on the horizontal struts. The members and connections of the bent tower are similar to those of the main tower, except that in the transverse face the struts are riveted to the column-web splice plates, and elsewhere are riveted directly to the column channel webs without connection plates and that the lateral diagonals are single riveted angles. The columns are made of pairs of 8-inch channels, latticed, and the other members are each made of four 2x2-inch angles.

Micanite has been the salvation of the tandem strain insulators used to support the cables of the great Carquinez span, of the Bay Counties Power Company,* for it combines great mechanical with dielectric strength. Unfortunately, however, micanite does not possess good surface insulation; that is to say, the shellac which is used to glue the layers of mica together oxidizes and offers a low creepage surface. This defect was overcome by combining with the micanite in this insulator the advantages of oil and



porcelain, using the porcelain where mechanical strength was not required.

The detailed sectional drawing and photograph of the unassembled parts will best describe the arrangement of this insulator. The conical porcelain tube here shown gives ample surface insulation between the drawbar and the steel collar corresponding to the difference of potential of the insulator, while the oil inside the copper tank acts in like service as well as to prevent arcing between opposite parts. The grooves shown on the flange of the micanite bushings are to increase the length of creepage surface, which, even in oil, is for this voltage not wholly to be relied on unless ample distance is given. The small cylinder or funnel on top of the tank is provided for filling it with oil and to inspect the oil level. While one of these strain insulators has sufficient insulation for the voltage used, it was deemed best to place two of them in series, so in case one gave out there would still remain a protection from grounding the cable.

It will, of course, be observed that no means are provided on the insulators themselves to prevent the interception of leakage to earth due to moisture on the surface, as in the case of the petticoat in line insulators. This, owing to the position in which the insulators are placed, makes such an arrangement impossible; therefore, a shelter was built over each set, and the entrance of the cable through the end of the house provided with a large window of plate glass with a hole 9 inches in diameter through which the cable passes.

OIL COOLING WORKS BOTH WAYS.

BY R. W VAN NORDEN.

A SINGULAR occurrence which came to my notice a few days ago, showing one of the benefits of oil insulation for power transformers in somewhat of a startling manner, may be of interest to the readers of THE JOURNAL.

A fire broke out somewhere in the machinery of a large mill in Sacramento, where sawdust is ground for the manufacture of powder. In a very short time the entire establishment was completely destroyed, together with much valuable apparatus. The fire was unusually hot and fierce. The motive power for the operation of the mill was derived from induction motors, which were on a floor directly over the reducing transformers, of which there were four. Two of the transformers were of the open, air-cooled type, the other two being of the newer oil-immersed and air-cooled type. To all appearances the two air-cooled transformers were red-hot; one of the oil transformers fell through the floor, the oil running out, and was badly jammed, but not so badly burned but that part of the coils can be used again. The remaining oil transformer kept its position and although the heat was so great as to make the tank red-hot down to the surface of the oil, and burned completely everything not metal above the oil, the oil itself did not catch fire and the transformer is not injured.

This certainly speaks well for the transformers and the oil used, to say nothing of the factor of safety obtained over the method of air cooling.

Vide THE JOURNAL, Volume XI, page 91, May, 1901.

CALCULATING POLYPHASE CIRCUITS.*

IN order to calculate the sizes of wires for two-phase and three-phase circuits, it is necessary to know (*a*) the current to be carried by each line, and (*b*) the permissible voltage drop between the beginning and end of the line.

The current in each line is as follows, according to the particular arrangement of lines in use:

Let W = the total apparent watts to be delivered

$$= \frac{\text{Total true watts to be delivered}}{\text{Power factor of the load}};$$

V = voltage measured between two lines, as shown in figures 1 to 4. Then

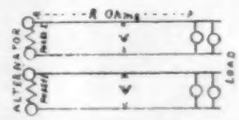


FIGURE 1.

1. For a four-wire two-phase transmission, as in figure 1: The current in each of the four lines $= \frac{W}{2V}$

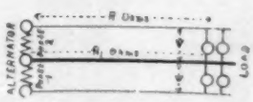


FIGURE 2.

and all four lines should be made of equal section.

2. For a three-wire two-phase transmission, as in figure 2:

The current in each of the two outer lines $= \frac{W}{2V}$;

the current in the common center line $= \frac{W}{\sqrt{2}V}$.

The section of the center line should, therefore, be made $\sqrt{2}$ times as large as either of the outer lines.

3. For a three-phase transmission with three lines, as in figure 3:

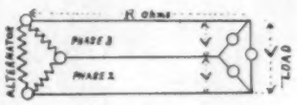


FIGURE 3.

The current in each of the three lines $= \frac{W}{\sqrt{3}V}$,

and all three lines would be of equal section.

4. For a three-phase transmission with three main lines and a fourth neutral line, as in figure 4:

The current in each of the three main lines $= \frac{W}{3V}$,

where V is the voltage between any one of the main lines and the neutral wire, and is equal to V_1, the voltage between any two main lines, divided by $\sqrt{3}$.

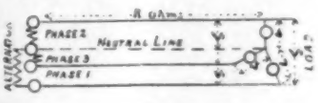


FIGURE 4.

All the above values are calculated on the assumption that the load is equally distributed amongst the phases. If the load consists entirely of motors this would naturally be the case, and even in the case of a mixed

*From *The Electrical Engineer*, London, Volume XXVII, page 313, March 1, 1901.

lightning and power load great care is usually taken to ensure equal distribution of the load, as any distinct departure from this state leads to bad pressure regulation. In the case of a three-phase transmission which has an unevenly distributed load, the four-wire arrangement (figure 4) should preferably be used; whilst for a two-phase unequally loaded case, the four wires (figures 2) are best. The section of the neutral wire in figure 4 is quite indeterminate, depending entirely on the closeness with which the phases are balanced; and if the balancing is exact, it can be dispensed with altogether.

Turning to the second point—the pressure drop—the determination is considerably more involved than for ordinary continuous-current lines. This arises from the fact that the drop depends not only on the ohmic loss in the lines, but also on the inductive drop and on the power factor of the load.

The ohmic loss can be calculated as follows:

Let C = the current in each main line determined as above;
R = the resistance of one main line;
v = the ohmic loss in voltage at a current = C amperes.

Then for a two-phase four-wire system (figure 1)

$$v = 2\,R\,C;$$

for a two-phase three-wire system (figure 2)

$$v = R\,C + \sqrt{2}\,C\,R_1 \cos 45\text{deg.}$$
$$= C\,(R + R_1);$$

where R_1 = the resistance of the central line, and $= \frac{R}{\sqrt{2}}$, if all the lines are worked at the same current density, as is usually the case.

For a three-phase three-wire system (figure 3)

$$v = 2\,C\,R \cos 60\text{deg.},$$
$$= R\,C.$$

And for a three-phase four-wire system (figure 4), assuming all three phases equally loaded, and no current in the neutral wire:

$$v = R\,C.$$

The inductive drop depends on the current in the line, on the size of the wire, and on the distances apart and relative positions of the different wires, and may be readily obtained for any given conditions by the aid of such a table as that published in *The Electrical Engineer*, London, June 25, 1897, page 813. The inductive drop in each phase of a two-phase four-wire, two-phase three-wire, three-phase three-wire, or three-phase four-wire (equal load distribution) system may be taken as practically the same as in a single-phase system transmitting one-half the apparent power at the same voltage and periodicity. This is on the assumption that the lines are properly arranged on the posts to prevent interference between the different phases, as described in the above-mentioned paper.

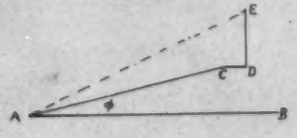


FIGURE 5.

Having decided the distance apart of the wires and the arrangement of wires on the parts, a size of wire (giving a reasonable current density) must be tentatively selected. The ohmic drop and the inductive drop must then be obtained as described above, and combined together by the accompanying diagram in order to determine the net resultant drop. Set off A B (figure 5) to represent the current in one phase. Draw A C (to represent the required voltage at the end of the line to some scale) at an angle ϕ to the line A B, such that cos ϕ = the power factor of the load for which the drop is to be determined. From C set off C D parallel to A B and equal to the ohmic drop to the same scale as before. From D draw D E at right angles to A B and equal to the inductive drop. Join A E. Then the difference between A E and A B is the total drop, and if this exceeds the permissible amount, the calculation must be repeated with a larger wire or with the wires placed further apart.

"THE JOURNAL'S articles on high potential transmissions and its illustrations of the high pressures which Californians indulge in, are indicative of the Western man," writes Robert Cartwright, M. A. S. C. E., Rochester, N. Y.

TRADE LITERATURE.*

"Small Multipolar Belt Type Motors" are described with full specifications in Bulletin No. 10, of the *Crocker-Wheeler Co.*, Ampere, N. J.

"Searchlight Projectors," in commercial and United States Government types, are described in Bulletin No. 4241 of the *General Electric Co.*

"High Voltage Ground Detectors" (type D), of the static variety, designed for voltages over 10,000, are illustrated and described in Bulletin No. 116 of the *Stanley Electric Mfg. Co.*

The "Bullock Electric Locomotive and Crane Car," especially applicable to efficient service in ship, iron and other heavy works' yards, is described in Bulletin No. 38 of the *Bullock Electric Mfg. Co.*

"Electric Locomotives for Mine Haulage," is a 75-page catalogue, 6x9 inches in size, and profusely illustrated, and describing in detail Baldwin-Westinghouse locomotives of this class. *Westinghouse Electric Mfg. Co.*

"High Voltage Testing Sets," of the type as adopted by the Standard Electric and the Bay Counties companies in their extremely high potential testing of insulators, are described diagrammatically in Bulletin No. 115 of the *Stanley Electric Mfg. Co.*

"The W. E. Series Alternating Current Arc System" is a 12-page Bulletin (No. 7009) giving a satisfying description of the new and original alternating current arc lighting system recently brought out by the Western Electric Co. *California Electrical Works.*

Westinghouse Bulletins: "No. 1040, "Self-Coiling Transformers" in large size, high voltage types for power transmission service. Complete data concerning voltages, weights of transformer, case, and oil, and dimensions are included. No. 1041, "Ammeters and Voltmeters," in the round pattern; No. 142, "Multipolar Generators and Motors" in belted types; No. 1043, "Generators, Rotaries for Electrolytic Work." *Westinghouse Electric Mfg. Co.*

General Electric Bulletins: No. 4229, "Large Oil Transformers;" No. 4242, "Direct Driven Continuous Current Generators" for incandescent and power service; No. 4243, "Induction Motors" of the three types known as forms L, K and M, with their distinguishing features; No. 4244, "Arc Lamps for Blueprinting;" No. 4245, "Switch for System of Remote Control" of arc and incandescent lamps, motors, etc., for central stations or a point some distance away. *General Electric Co.*

WILLIAM MCKINLEY, HIS LIFE AND WORK, by *Gen. Charles H. Grosvenor.*

President's life long friend, comrade in war and colleague in Congress. Was near his side with other great men when his eyes were closed in death. Followed the bier to the National Capitol and to Canton. The general requires a share of the proceeds of his book to be devoted to a McKinley monument fund. Thus every subscriber becomes a contributor to this fund. Millions of copies will be sold. Everybody will buy it. Orders for the asking. Nobody will refuse. Elegant photogravure portrait of President McKinley's last picture taken at the White House. You can easily and quickly clear $1000 taking orders. Order outfit quick. Chance to prove success, secure yearly contract and become manager. Outfits free. Send 12 cents in stamps to pay expense of wrapping, packing and mailing elegant prospectus. Taking ten to fifty orders daily. 50,000 copies will be sold in this vicinity. Address, *The Continental Assembly*, Odd Fellow's Building, Sacramento, Cal.

"THE JOURNAL is a paper that is a credit, not only to the Pacific Coast but to all the country," writes Mr. J. T. Stockdale, Schenectady, N. Y.

"I do not pay any subscription with more pleasure than that for THE JOURNAL," writes Mr. Frank Bourne, Mt. Vernon, N. Y.

*Catalogues mentioned in this department will be mailed gratuitously on application to the concerns publishing them. When writing, mention THE JOURNAL OF ELECTRICITY, POWER AND GAS.